OMP-26 -AN INTERACTIVE SCHEDULING '1'001 , FOR THE 26 METER SUBNETWORK

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Abstract

operations Mission Planner for the 26 Meter (26M) Antenna Subnetwork (OMP-26) is an interactive scheduling tool developed by the Jet Propulsion Laboratory (J]'],) to assist in allocating the Deep Space Network (DSN) 26M antennas to support Earth-orbiting Spacecraft (SC), Prior to integrating OMP-26 into the 26M scheduling arena, the tex{-based, labor-intensive task lacked the sufficient means to support the 1 99? mission support increase. Therefore, JPL developed the OMP-26 interactive scheduling tool to automate the time consuming tasks of the existing, manual scheduling process. OMP-26 has addressed the scheduling dilemma by assisting schedulers 10 identify and resolve conflicts more quickly through its graphical display features and constraint-checking editing capability. Although OMP-26 has reduced the scheduler's existing workload by easing the identification and resolution of conflicts, it will not meet the needs of another mission support increase to occur by 1995. Therefore, future plans for OMP-26 involve transitioning from a solely interactive scheduling tool to one that is highly automated and more powerful.

Background

The DSN 26M antenna subnetwork consists of three antennas located at the Goldstone (United States), Madrid (Spain), and Canberra (Australia) Deep Space Communications Complexes. These antennas currently support a variety of Earth-orbiting SC as well as the Space Shuttle. SC support occurs only when its orbit places it in view of the antenna. The view period is the duration between the SC rise above the horizon (relative to the antenna) and set below the horizon. For the SC supported by the 26M antennas, typical view periods range from 8 - 15 minutes.

SC support, also dc.fine.d as an activity, consists of three major parts: Precalibration (PRE), the track itself, and postcalibration (POST). PRE is the time dedicated to configuring, calibrating, and testing the equipment required to support the SC. The track, delimited by a Beginning of 'Track (BOT) and End of Track (EOT), identifies when the antenna actually communicates with the SC. The track generally corresponds to the view's rise and set. Finally, the POST is the time. when the equipment is deconfigured and released for use with another SC. How these components relate to the start and end of an activity (SOA . EOA) to be scheduled is pictured in Figure 1.

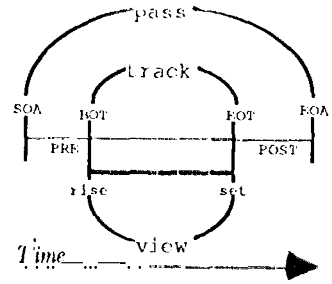

Figure 1. Activity Composition.

26M Scheduling

Until June 1992, generating a schedule for the. 26M subnetwork was a manual process spanning three phases: Strawman, Forecast, and 7-Day, to produce a o]tc-week schedule.

The Strawman schedule was produced three weeks prior to execution. To create the Strawman, the schedulers ran a utility program, residing on the Network Operations Control Center Support Subsystem (NSS), to generate a file containing all view periods for the week to be scheduled. This file was exported to a Personal Computer (PC) where the scheduler ran a utility, using the view file as input, 10 (1) extract 26M views meeting a minimum duration, (2) generate passes, and (3) output a batch file. Since this file contained unschedulable activities (those with projects requesting tracking time on antennas that are unable to support them), the scheduler used a PC text editor to manually perform further filtering. The altered batch file was then sent back to the NSS to update a scheduling database from which a sorted list of all activities was generated.

This listing, pictured in Figure 2, itemized each activity and its conflict status. The conflict status column, labeled "FLAG" in Figure 2, contained either a line number correlating to the line causing the conflict or an asterisk indicating that more than one line is causing conflict. The scheduler manually reviewed this listing by scanning this column to identify sets of similar line numbers. Adjustments were made for easily resolved conflicts, while more difficult conflicts were highlighted and seal to the flight projects for review.

The various projects submitted their changes to the Strawman schedule for incorporation into the initial Forecast schedule. Feedback from the projects came by fax, paper, or batch files. Depending upon the feedback media, alterations to the schedule were made by interactive command line editing or through batch file submittal. During this phase, two weeks prior to schedule

DSN 7-DAY STRAWMAN SCHEDULE
ACTIVITIES LISTING
WEEK NO. 18 *** 27 APR 92 - 3 MAY 92

NO.	DAY	START	BOT	EOT	END	DSS	USER	ACTIVITY	PASS	CONFIG	WRK	FLAG
39	118	1301	1331	1343	1343	46	N1M7	PDF - A C TR DUMP	8210	C00AN1	1A1	
40	118	1343	1343	1413	1413	46	N1M7	PB PDF- B	8210	C000N1	1A5	
41	118	1449	1534	1545	1545	66	SOLA	TKG PASS	3878	C00AP0	1A1	
42	118	1500	1500	2300	2300	16	DSS	MAINTENANCE		NONE	2A1	0061
44	118	1535	1620	1627	1627	46	SOLA	TKG PASS	3879	C00AP0	1A1	
45	118	1545	1545	1645	1645	66	SOLA	PLAYBACK	N1B	C000P1	1A5	*
46	118	1627	1627	1727	1727	46	SOLA	PLAYBACK	N1B	C000P1	1A5	
48	118	1632	1717	1727	1727	66	SOLA	TKG PASS	3879	C00AP0	1A1	*
50	118	1727	1727	1827	1827	66	SOLA	PLAYBACK	N1B	C000P1	1A5	*
53	118	1816	1901	1910	1910	66	SOLA	TKG PASS	3880	C00AP0	1A1	*
55	118	1930	1910	2010	2010	66	SOLA	PLAYBACK	N1B	C000P1	1A5	
57	118	2043	2128	2138	2138	46	SOLA	TKG PASS	3882	C00AP0	1A1	
60	118	2105	2150	2202	2202	66	N1M7	PDF- A C TR DUMP	8215	C00AN1	1A1	
61	118	2123	2153	0248	0250	16	HIPP	TKG PASS	2121	C00KX5	1A1	0042
63	118	2138	2138	2238	2238	46	SOLA	PLAYBACK	N1B	C000P1	1A5	*
64	118	2202	2202	2232	2232	66	N1M7	PB PDF-B	8215	C000N1	1A5	
65	118	2226	2311	2321	2321	46	SOLA	TKG PASS	3883	C00AP0	1A1	*
66	118	2248	2333	2347	2347	66	N1M7	PDF-A C TR D UMP	8216	C00AN1	1A1	
67	118	2300	2342	2353	2353	16	SOLA	TKG PASS	3883	C00AP0	1A1	0061
68	118	2321	2321	0021	0021	46	SOLA	PLAYBACK	N1B	C000P1	1A5	*
70	118	2347	2347	0017	0017	66	N1M7	PB PDF-B	8216	C000N1	1A5	
71	118	2353	2353	0023	0023	16	SOLA	PLAYBACK	3883	C000P1	1A5	0061
72	118	2356	0026	0041	0041	46	N1M7	PDF - A C TR DUMP	8216	C00AN1	1A1	*
76	119	0043	0041	0111	0111	46	N1M7	PB PDF- B	8216	C000N1	1A5	
77	119	0042	0127	0137	0137	16	SOLA	TKG PASS	3884	C00AP0	1A1	0061
79	119	0137	0137	0207	0207	16	SOLA	PLAYBACK	3884	C000P1	1A5	0061
80	119	0140	0210	0223	0223	46	N1M7	PDF- A C TR DUMP	8217	C00AN1	1A1	
83	119	0223	0223	0253	0253	46	N1M7	PB PDF-B	8217	C000N1	1A5	
84	119	0226	0311	0319	0319	16	SOLA	TKG PASS	3885	C00AP0	1A1	0061
86	119	0319	0319	0349	0349	16	SOLA	PLAYBACK	3885	C000P1	1A5	
87	119	0400	0400	0800	0800	66	DSS	PET		NONE	2A5	

Figure 2. Strawman Report.

execution, the scheduler also merged requests from projects originally excluded in the view file. A more refined version of the Forecast was generated and again sent to flight projects for their review.

The final phase of scheduling resulted in producing the 7-Day schedule. Similar to the conflict resolution process performed during the Forecast phase, the flight projects submitted their new or changed requests to the schedulers. At this point, the schedulers also compared the resource requirements for the 26M subnetwork to those of the other DSN antenna subnetworks to identify any shared resource or bandwidth conflicts. Three days prior to 7-Day schedule execution, it was forwarded, conflict-free, to the real time scheduling arena.

Although the manual scheduling process described above handled the 26M scheduling needs, the Summer 1992 mission load increase was predicted to jeopardize the ability to generate schedules within the specified time constraints. Enabling the existing scheduling staff to meet the Summer 1992 requirements was the primary purpose for the development of OMP-26.

Objectives

The 26M scheduling process needed to be simplified, while preserving interfaces to the NSS report generation software. To meet these goals, five objectives had to be met.

One objective was to reduce the amount of computers involved. All processes operating on the PC could be emulated in one environment. Additionally, all operations between the NSS and the scheduling tool could be executed on one platform by employing a communications package.. With these changes in place, the users would have just one computer on their desktop.

The second objective was bawd upon a constraint imposed by the DSN. Because the NSS interface served as the central database for all scheduling activities (26M, 34M, and 70 M), the interface ICI this system had to be preserved. It was also necessary to minimize any possible confusion over the roles of the two schedule databases (NSS and OMP-26) and the relationship between them.

A third objective was to reduce the amount of command line edit ing required to effect changes in the schedule. The scheduling tool could generate batch files capturing all transactions made during the tool's operations. These batch files could then be exported to the NSS environment and serve to update the NSS database, thus satisfying the NSS interface requirements.

Another objective was to automate the conflict identification process. Rather than matching line numbers to conflicting activities, the interactive scheduling tool could graphically display conflicts through Strip and Gantt charts and offer navigational capabilities to maneuver around the schedule.

The final and most important objective involved improving the conflict resolution process. Through graphical editing techniques, the user could manipulate activities by shortening, moving, deleting, or adding them to work towards a conftict-free schedule. Search and display features could enable the user to manipulate schedule data yielding better results.

Approach

Based upon their knowledge of past OMP research conducted at JPL, the Telecommun ications and Data Acquisition (TDA) Mission Support and DSN Operations Office approached JPL's Advanced information Systems Section 10 develop a scheduling tool. The proposed tool coupled JPL's past OMP scheduling msc.arch and the customer's objectives to satisfy 26M scheduling demands. JPL translated the above 26M scheduling objectives into the design of OMP-26 and produced a variety of capabi I it ies described below.

Single Platform

All 26M scheduling operations are perfor med on one machine, a Macintosh, Since OMP-26 automatically removes unschedulable views and extracts 26M views meeting a minimum duration from the view file, and generates passes and playbacks, the PC is no longer needed. "J he user also moves files between the OM})-26 and NSS environments on one machine. Therefore, the physical terminal from which the utility programs ran is unnecessary.

OMP-26 Graphical User Interface

The OMP-26 interactive scheduling tool supports conflict identification and resolution through its Graphical User Interface (GUI) [1]. The GUI consists of a multi-window system, pull down menus, a text editing capability, and mouse-sensitivity. The interface follows the user interface guidelines for Macintosh application progra ms.

Information Displays

OMP-26 uses two types of timeline displays, as shown in Figure 3, to represent the schedule: Strip Charts and Gantt Charts. Information contained in the Strip and Gantt Charts are lied 10 a timeline which serves 10 synchronize the temporal information shown on both displays. Strip chalk, which arc color-coded histograms depicting the level of individual antenna usage, allow the scheduler to quickly identify regions of conflicts (red), normal resource subscription (green), and rc.source availability (gray). Gantt Charts show the view periods (blue bars) and specific assignment of SC activities (white l-beams) to the antennas.

'1'0 read the time at a specific point on a Snip or Gantt Chart, the user positions the mouse pointer over that point and reads the time information on the year, Day of Year (DOY), hour, and minute in the timeline information box, as seen in Figure 3. As the mouse is moved across the timeline, OMP-26 automatically updates the timeline information box.

Three types of status information arc accessible from the timelines: conflict, activity, and view. Clicking on a point in the Strip Chart highlights (in the Gantt Chart) all activities in conflict at that point on the timeline. It also displays their project and type in the Status line.. Clicking on an I-beam highlights it and updates the Status line with the activity's project and type. Finally, clicking on the blue view bar, highlights it and causes the selected view's project, antenna, rise, and set to be displayed on the Status line.

Once OMP-26 is invoked, the timeline is automatically set 10 a 7-day scale. To display greater detail in the Schedule Window, the large magnifier icon is selected for resolutions of 1 -day, 12-hours, and 6-hours. The small magnifier icon is selected to zoom out. When examining zoom levels other than the 7-day, the entire week-long schedule is not in vim. To display another portion of the schedule, the user drags the thumb along the scroll bar (pictured in Figure 3) and releases the mouse button when the desired time is reached. This action shifts the display to the time shown in the scroll bar information box,

Functional Displays

To assist the scheduler in resolving conflicts, several functional displays have been incorporated into the OMP-26 GUI. These displays enable the user to edit the schedule, create new activities, and conduct searches.

Detailed, temporal information regarding an activity is textually displayed and editable in the Act ivity Information Window (AI W), as seen in Figure 4. Double clicking on a Strip Chart or I-beam brings all activities

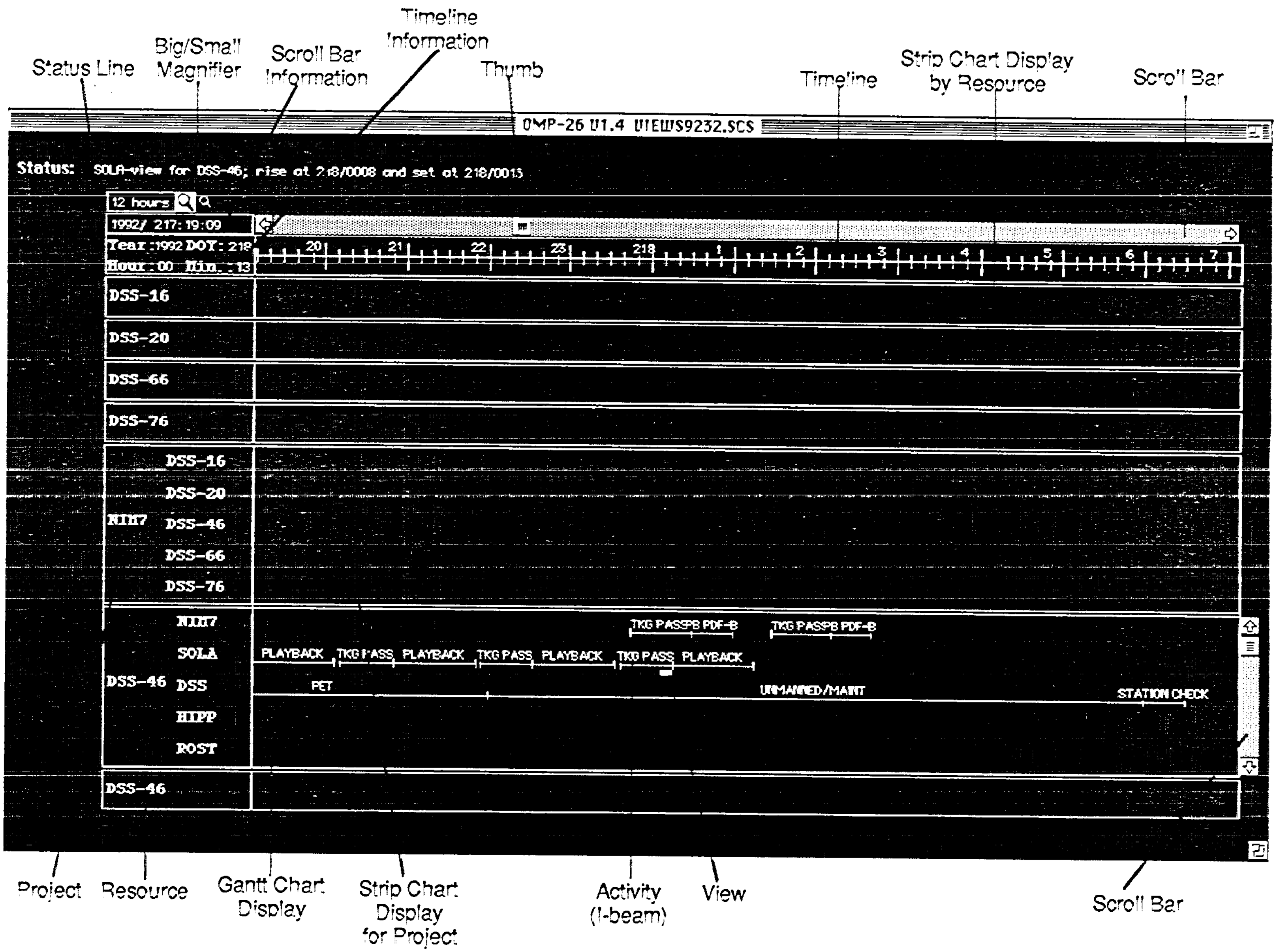

Figure 3. Schedule Window.

scheduled during the time-slice that was selected into the AIW. The AIW assists the scheduler in resolving conflicts through these editing features:

- Deleting: The delete operation is available from both the AIW and Schedule Window. Both operations effect the reflected change in the Snip and Gantt charts,

- Undeleting: Undeleting brings the activity back into the schedule and replaces it in the Strip and Gantt charts.

- Modifying: Modifying activities involves altering the. desired text fields in the AIW. Whenever the user edits temporal fields, their changes are propagated across all affected time fields by the constraint checking editor.

- Locking: Locking an activity prc.veals any modifications or deletions from taking place until the user unlocks it.

OMP-26 offers three options for creating an activity: creating one from an existing view period, creating a new vie\\' period and activity simultaneously, and generating an activity without a view. These feat urcs are accessed through a special Create Activity window.

To locate activities in OMP-26, the user activates the Search feature. Search criteria, entered in a special Search window, include activity types, projects, antennas, and temporal ranges. After locating the search data, OMI '-?6 displays the number of found activities matching the criteria. At this point, the user selects the option to display the found activities in the AIW.

Input/Output Processing

To maintain the interface between OMP-26 and the NSS, OMP-26 uses batch files to transfer schedule data. Schedule modifications are received via batch files which serve to update the OMP-26 database. These input files are generally submitted by the projects. For output processing, all transactions occurring during OMP-26 operations recaptured in the form of a batch file. This file is then transferred to the NSS environment to update its database.

Implement ation

OMP-26 is based upon previous research of artificial intelligence-based scheduling under the Operations Mission Planner (OMP) project [2]. Because of the extremely short deadline (3 months to create an operational tool) imposed by the DSN, it was decided to first provide a manual tool to assist the DSN schedulers in handling the Summer 1992 workload increase, and to later provide an automated scheduling capabilities needed to support the 1995 increase.

OMP-26 is implemented on a Macintosh personal computer using Allegro Common 1,1S1'. It runs under Mac OS 7.0 or greater and employs a custom user interface, based on the OMP research prototype interface, in order to meet the performance requirements of the system

The user was involved in all phases of OMP-26 development and their continuous involvement helped to define development phases and deliveries. One of the goals of user involvement was to be continuously aware of capabilities that were needed to maximize scheduling efficiency and accuracy. This focused the development team when prioritizing the user's wish list, based on development difficulty and the criticality of the feature(s). This list also prevented the development of "pretty" features over those that were more critical. Also, any deficiencies in OMP-26 capabilities, with respect to the NSS, were also of high priority,

Training was a critical to the successful deployment of the OMP-26 tool, The users had no previous experience with Macintosh computers or graphical scheduling tools, so a comprehensive training program was needed. In order to facilitate training (without impacting the on-going scheduling operations) members of the OMP-26 development team worked along side the DSN schedulers to generate and edit schedules using OMP-26.

Another aspect of training addressed the way in which a schedule was generated and conflicts were resolved. The OMP-26 processing method was very different from the method to which the user was already accustomed, thus this new method required that the user understand the sequence of operations. This training approach served to educate the OMP-26 development team in turn by revealing limitations in the tool. Working together, the development team and users were able 10 identify several desired features which would enhance productivity.

Application Use

The transition of OMP-26 into the 26M scheduling environment was a smooth one. Although the Strawman, Forecast, and 7-Day schedules still had to be generated within the same time periods, the methods employed to produce these schedules varied significantly from those exercised prior to OMP-26's application.

To begin a Strawman schedule, the scheduler (from the OMP-26 environment) accesses the NSS environment, via a communications package, to generate the required view file. Once this file is created and exported back to the OMP-26 environment, the user loads it into OMP-26. The loading process performs the following steps: extracts only those views meeting minimum durations as well as those deemed schedulable; creates passes and playbacks from legal views by including PRE, and POST; generates regularly scheduled activities, such as maintenance; and presents all scheduled items through Strip charts. The

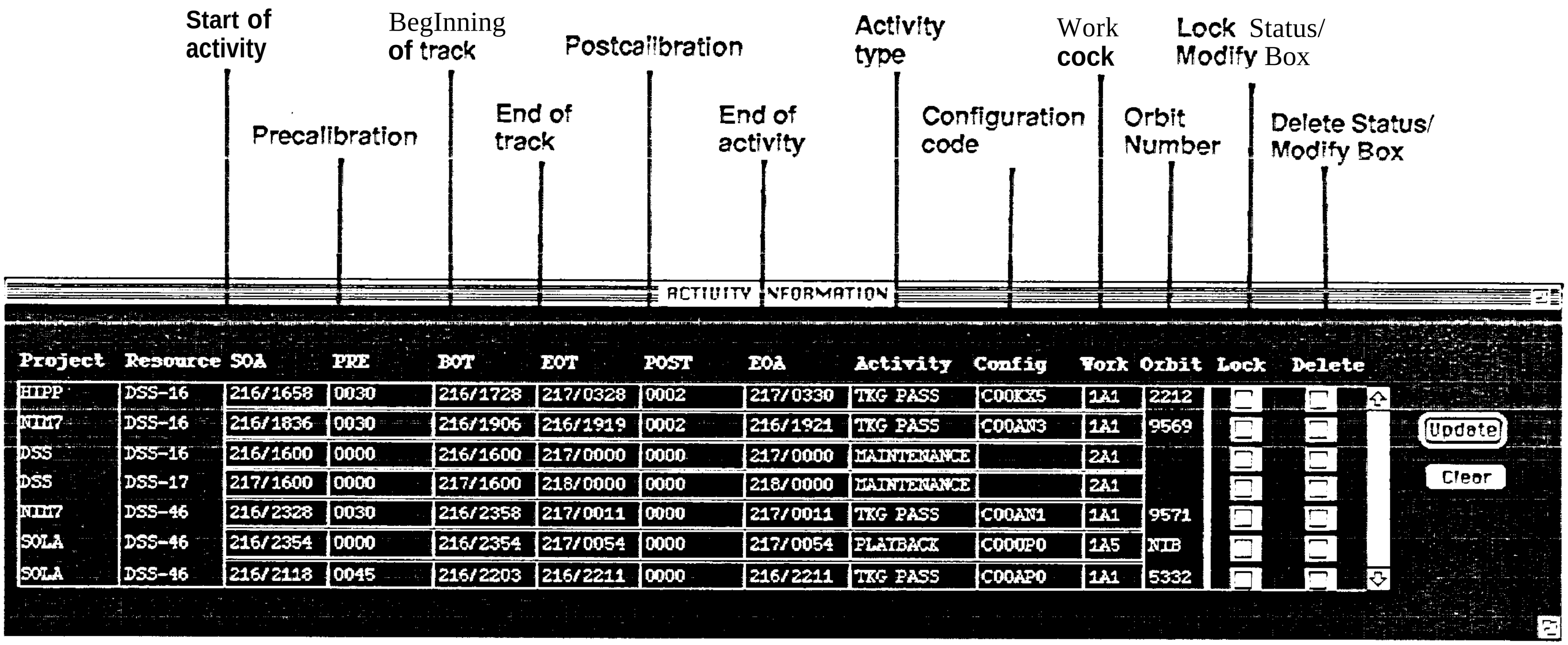

Figure 4. Activity Information Window.

scheduler then clears the highest priority items by using the OMP-26 conflict identification and resolution features.

At this point, the user saves all OMP-26 transactions to a batch file. Using the communicant ions package 10 export the batch file to the NSS environment, the scheduler runs the batch file and generates the report to be sent to flight projects for their feedback.

Change rc.quests from the projects still comes by fax, paper, or batch files. After exporting all batch files to the OMP-26 environment, the user immediately submits them to update the OMP-26 database. Paper and fax entries are easily integrated by taking advantage of OMP-26's editing capabilities.

The refinement cycle is repeated for each phase by distributing new versions of the schedule to the projects, obtaining, their feedback, and processing the changes. Similar to the 7-Day schedule process, the scheduler compares resource conflicts with other DSN subnetworks and makes the required adjustments to the 26M schedule. Finally the 7-nay schedule is ready to be forwarded to the real t i me scheduling group.

Benefits

OMP-26 has met its initial objectives and has many proven benefits. It has been operational since July 1992 and has enabled the DSN scheduling organization to handle a two-fold increase in workload while cutting operations time by 33%. Also, the tool is "smarter" in that it only schedules valid activities. Finally, only one machine is needed to perform all scheduling and data transfer tasks, which previously required two machines.

Lessons Learned

Because OMP-26 was impacting 26M scheduling, it was important to quickly establish and implement methods to gain the user's trust in the tool. This confidence was gained by the following concepts:

- Domain Knowledge: To ease the transition into using OMP-26, it was a prerequisite to become intimately familiar with the 26M scheduling process. By identifying how OMP-26 functionality mapped to the 26M scheduling domain, the user \vas enabled to recognize similarities and accept the tool more readily. Drawing these parallels would have been an impossible assignment without gaining the domain knowledge.

- User Interaction: To avoid any user anxieties accompanied by altering an already familial task, it was imperative to conduct aggressive training programs and assist whenever needed. With each delivery, an OMP-26 team member directed training sessions emphasizing the tool's latest features. A team member was also available. at all times to guide the user through any problem areas.

- Bug Fixes: It was crucial to quickly respond to bugs the user encountered during OMP-26 operations because of the daily dependence on the tool. It was also important to develop work-arounds allowing the user to perform their job until the problem was fixed.

Future Plans

Based on the success of the OMP-26 interactive scheduling tool, there are several efforts underway which are addressing DSN scheduling problems. One primary goal of this work is to decrease the cost of DSN scheduling. This goal includes not only advance schedule generation, but also the realtime maintenance of the schedule and the sustaining engineering necessary to keep the 1001 current (the mission scl, priorities between spacecraft, and operational conditions arc continuously changing). Future work focuses on three areas: automation, maintenance, and expansion to support all phases of DSN operational scheduling and all subnetworks of antennas:

- Automated Scheduling: To accommodate the upcoming 199S mission load, development is underway on an automated version of the OMP-26 scheduling tool. This tool will automatically resolve conflicts and generate a schedule.

- User Maintenance: Currently, the user depends upon the OMP-26 team to maintain the project pertinent data, such as default PRE/POST durations and supported projects/antennas, used to generate activities. It is a future goal to implement a GUI and underlying database so that the user becomes responsible for maintaining this data. in addition, once the automated system becomes operational, the user will need the means to maintain the knowledge bases that drive the automated scheduler.

- Real-time Tool: Current OMP-26 work focuses on the generation of schedule prior 10 realtime operations. Realtime operations arc responsible for executing the, schedule and handle hundreds of change requests each week. The OMP-26 interactive and automated tool will be used as a base.line to build a pilot tool, targeted for realtime schedulers, for expediting and optimizing schedule changes with minimal schedule perturbation.

Conclusions

The OMP-26 interactive scheduling tool has been successfully deployed to support scheduling of the DSN 26M subnetwork. Since its deployment in July 1992 , it has increased productivity even in light of increasing workload. The tool has received a high level of user satisfaction and will be used as a baseline for the development of other tools to support DSN scheduling requirements.

Acknowledgments

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[2] E. Biefeld & L. Cooper, "Automated Scheduling Via Artificial Intelligence," NASA Tech Briefs, Volume 15, Number 8, August 1991, p.86.